Cake creep during filtration of flocculated manure

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Cake creep during filtration of flocculated manure

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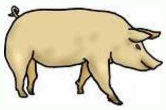
Introduction

Swine production is more and more concentrated on large farms. Large amount of manure are produced and several problems have been reported such as losses of nutrients to the environment, ammonia emissions, and odor. Manure separation may solve some of the problems.

Manure can be separated into a high dry-matter and nutrient-rich fiber fraction and a liquid fraction. It is thereby possible to

1. Reduce cost for transportation of nutrients to fields with nutrient defiant
2. Adjusting the distribution of nitrogen and phosphorus on the fields with crop demands
3. Minimize odor problems
4. Remove heavy metals



Sieves, screw presses, belt presses, and decanter centrifuges have been used. Further, chemicals e.g. $FeCl_3$, $Al_2(SO_4)_3$, $Ca(OH)_2$ or polymers have be added to flocculate manure and improve removal of dry matter and phosphorus from the liquid fraction.

***Figure 1**. Flocculated manure.*

Irregular water-containing flocs (0.1 - 5 mm) formed during flocculation

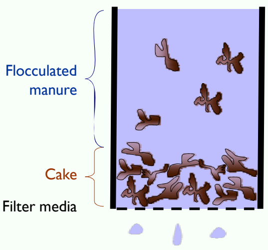
Lab-scale experiments can be used to study the dewatering process. Such knowledge can be of great value in order to optimize the chemical pre-treatment and dimensioning the equipment. However, the problem is that the existing models cannot describe dewatering processes for flocculated manure satisfying. The idea of this work is to used pressure filtration to study dewatering of flocculated manure in order to better understand the process

Filtration theory

During filtrations, a suspension is pressed towards a filter medium permeable to the liquid but impermeable to the particles. Particles therefore deposits on the media forming a three-dimensional network structure (cake). The filtrate rate is mainly controlled by the hydraulic resistance of the cake.

***Figure 2.** Filtration principle*

Flocs are deposed on the filter media during the filtration and forms a continuous network structure (cake). The liquid have to pass the cake during the dewatering process and the filtrate rate is mainly determined by the properties of the cake.



In conventional models, the filtrate rate (q) is a function of applied pressure (P), filtrate viscosity (μ), specific filter-cake resistance (α), and mass of cake per media area. It is assumed that the mass of cake increase proportional with filtrate volume.

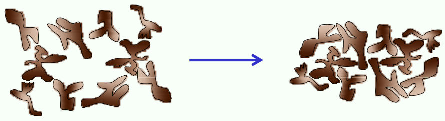
$$q = \frac{P}{\mu \alpha \omega}$$

However, the model do not fit filtration data for flocculated manure

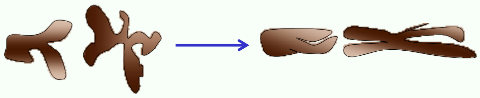
Compression of cakes

The specific filter-cake resistance depends on cake porosity. At low pressure a loosely packed cake is form with low resistance. At higher pressures the cake is compressed and the resistance increases. Hence, compressible cake are more compact near the filter media than at the top. Different mechanism can be suggested for cake compression, such as:

Rearrangement:



Deformation:



Compression:

It is in the conventional filtration theory assumed that cake porosity is a unique function of pressure. As a consequence the specific filter-cake resistance is constant during filtration. The filtration theory has been tested on inorganic particles such as anatase, bentonite, and china clay. Compression of these cakes is mainly due to rearrangement. Nevertheless, both deformation and compression of individual particles are important for water-containing particles. Deformation and compression of individual particles are time-dependent processes (creep phenomena). Hence, the cake porosity is a function of both pressure and time.

Simple model for cake resistance

The specific filter-cake resistance has been calculated by introducing an initial resistance (α_0), a resistance increase ($\Delta\alpha$) and a time constant (τ):

$$\alpha = \alpha_0 + \Delta\alpha\left(1 - e^{-t/\tau}\right)$$

The equation has been used to simulate a filtration experiment of swine manure flocculated with $FeCl_3$ and cross-linked cationic polymer.

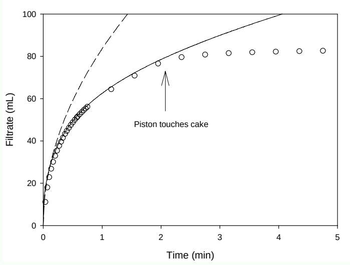


***Figure 3.** Filtration of manure*

Filtration of 56 g/L manure at 2 bar.
Dotted line (conventional model): $\alpha = 2.4 \cdot 10^4$ m/kg
Solid line (creep model) : $\alpha_0 = 2.4 \cdot 10^4$ m/kg, $\Delta\alpha = 7.2 \cdot 104$ m/kg, and $\tau = 75$ s.

It is thereby possible to simulate the data until the piston touches the cake.

Final remarks

Deformation and compression of individual water-containing particles leads to cake creep and cannot be simulated by existing filtration models. Hence, new models for cake compression are needed. These models have to be tested by using simple well-characterized model materials.